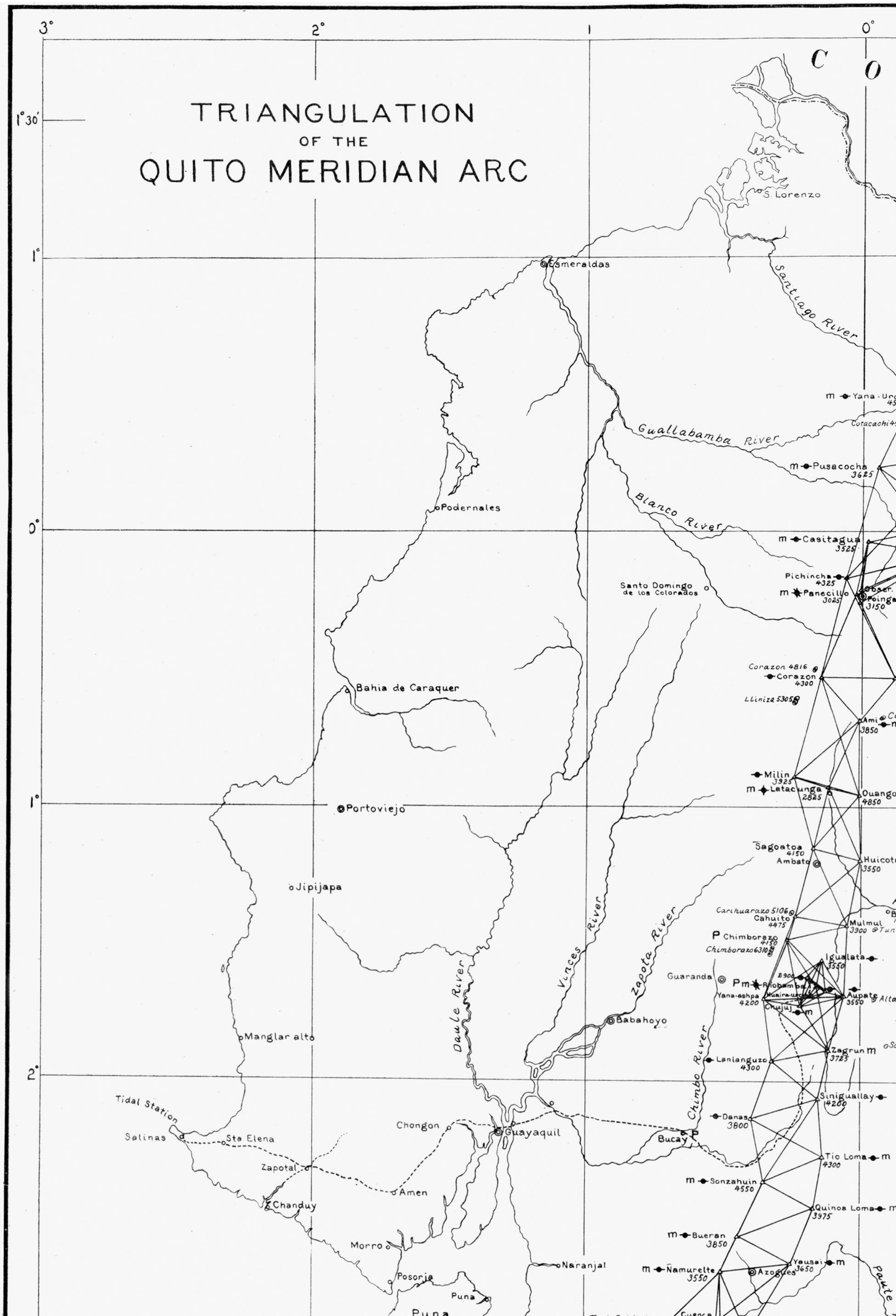
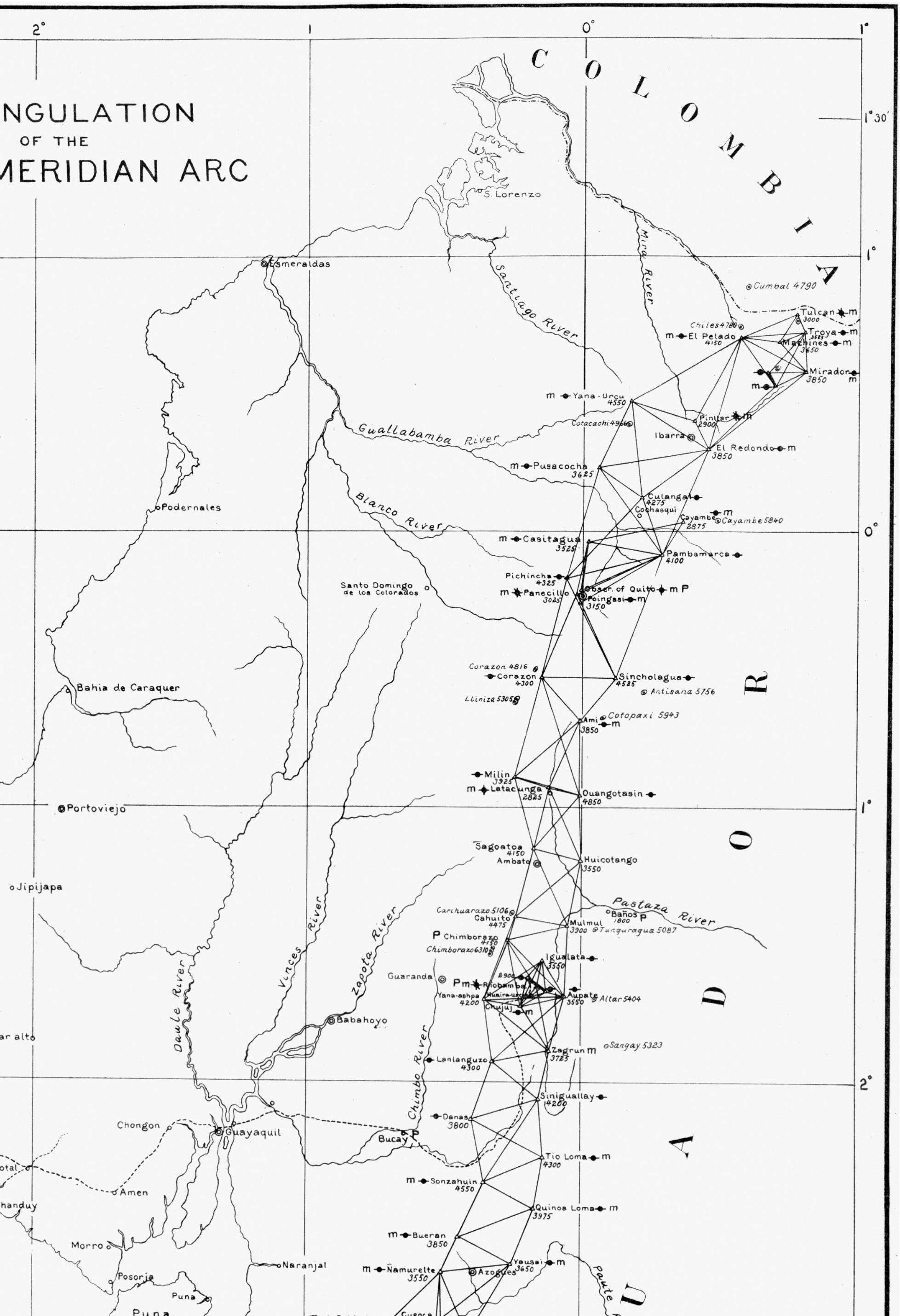
TRIANGULATION OF THE QUITO MERIDIAN ARC

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MERIDIAN ARC
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Troya
Machines
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Chiles 4780
El Pelado
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Mirador
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Yana-Urcu
4550
Cotacachi 4966
Pinllar
2900
Ibarra
El Redondo
3850
Guallabamba River
Pusacocha
3625
Culanga
4275
Cochasqui
Cayambe
2875
Cayambe 5840
Podernales
Blanco River
Casitagua
3525
Pambamarca
4100
Pichincha
4325
Santo Domingo
de los Colorados
Panecillo
3025
Obser. of Quito
Poingasi
3150
Corazon 4816
Corazon
4300
Sincholagua
4525
Antisana 5756
Bahia de Caraquer
Lliniza 5305
Cotopaxi 5943
Ami
3850
Milin
3925
Latacunga
2825
Ouangotasin
4850
Portoviejo
Sagoatoa
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Ambato
Huicotango
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Jipijapa
Carihuarazo 5106
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Pastaza River
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Mulmul
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Chimborazo 6310
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Puna
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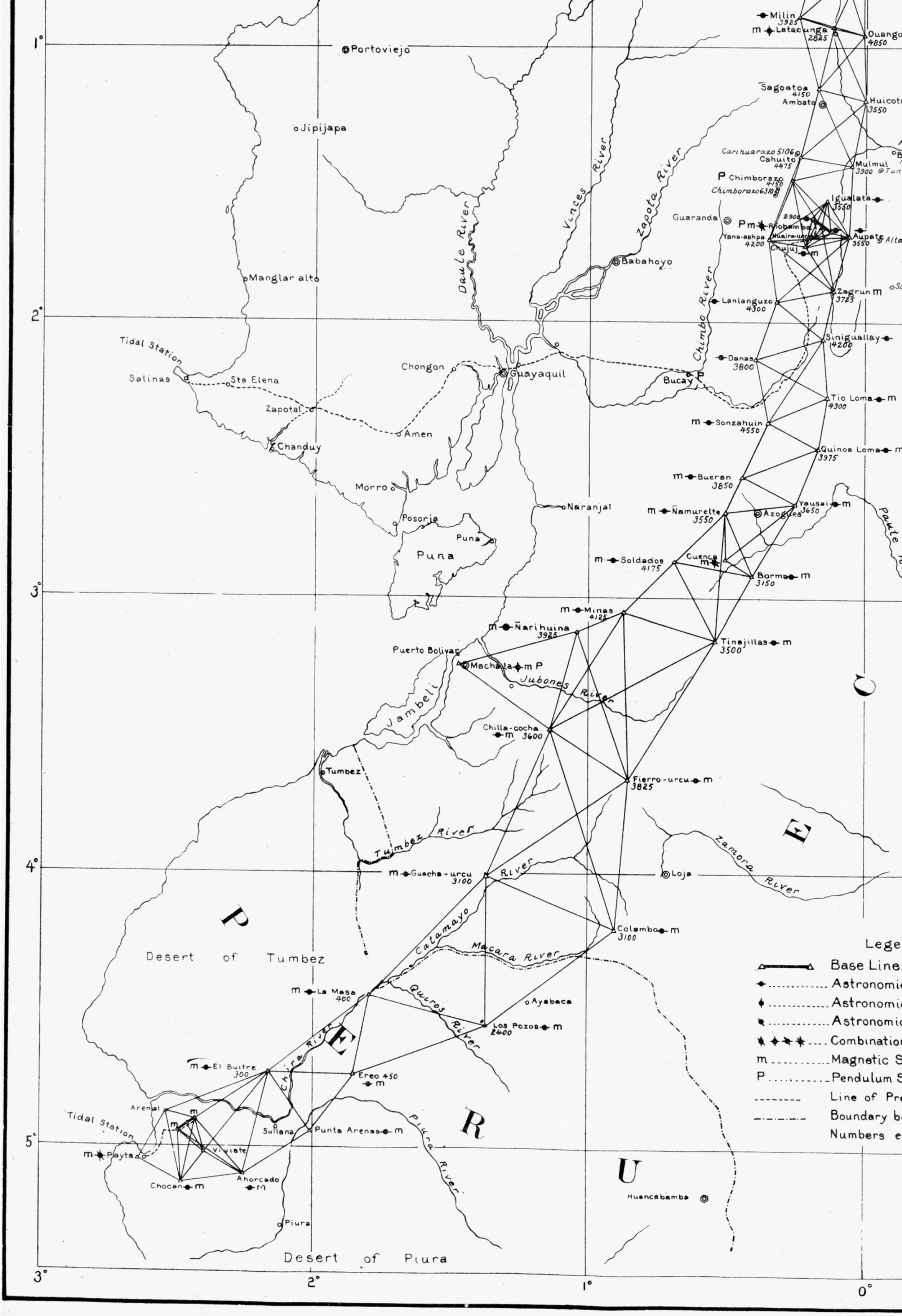

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Quinoa Loma m 3975
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m Minas 4125
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Machala m P
Tinajillas m 3500
Jubones River
Jambeli
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Desert of Tumbez
Catamayo
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m La Masa 400
Quiros River
Ayabaca
Los Pozos m 2400
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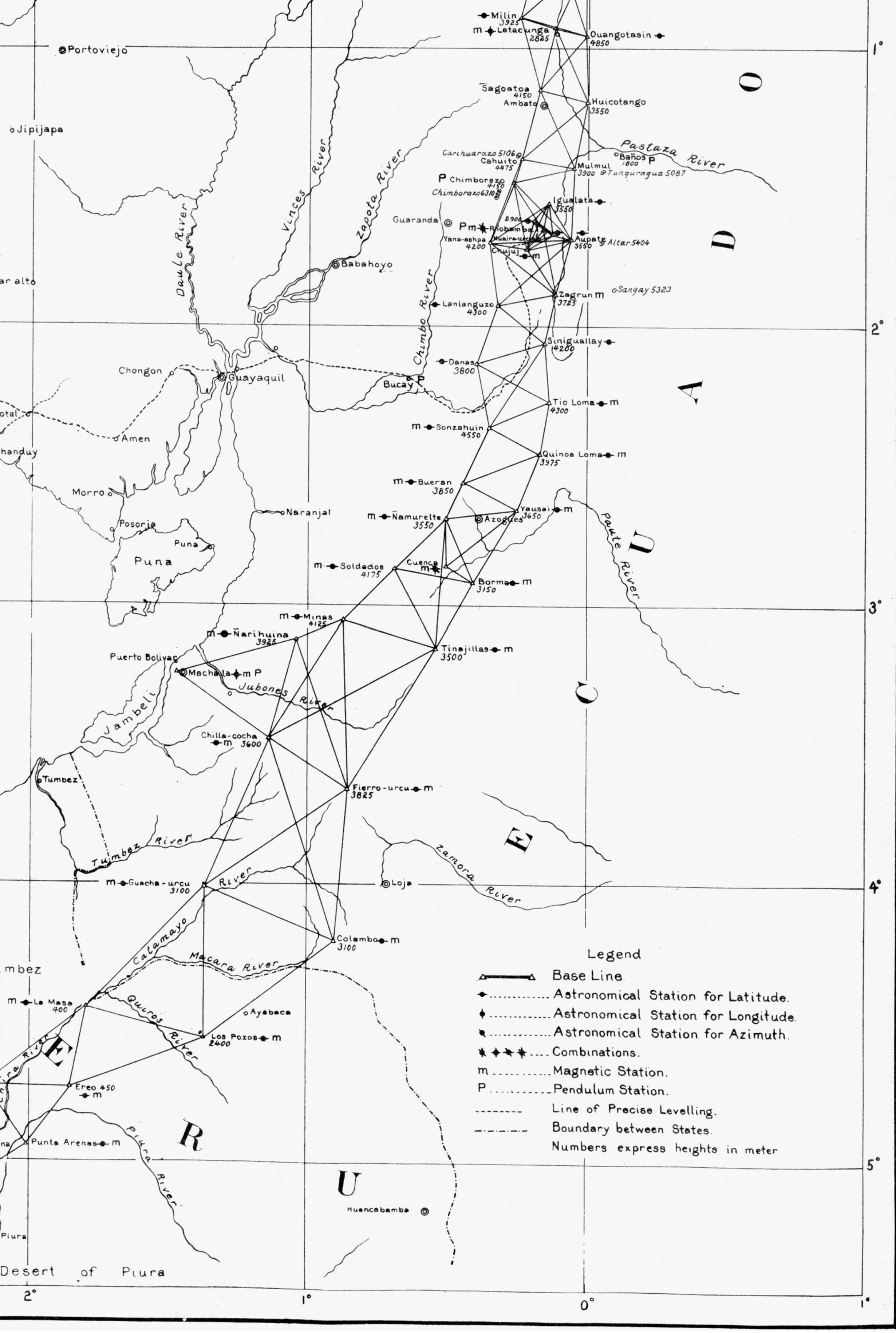

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Macara River
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Quiros River
Ayabaca
Los Pozos 2400
Ereo 450
Punta Arenas
Piura River
Huancabamba
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Legend
Base Line.
Astronomical Station for Latitude.
Astronomical Station for Longitude.
Astronomical Station for Azimuth.
Combinations.
Magnetic Station.
Pendulum Station.
Line of Precise Levelling.
Boundary between States.
Numbers express heights in meter
1°
2°
3°
4°
5°
0°

BULLETIN

OF THE

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THE RECENT SCIENTIFIC MISSIONS FOR THE MEASUREMENT OF ARCS OF THE MERIDIAN IN SPITZBERGEN AND ECUADOR.

BY

G. W. LITTLEHALES.

The annals of scientific advancement have recently been enriched by two achievements which have involved distant and perilous operations on the part of a joint commission of Russian and Swedish scientists in Spitzbergen and of a commission of French scientists in Ecuador and Peru, and which, in their results, are destined to exercise an important influence in the larger problems of geography and to form a contribution to the array of observational facts which lie at the foundation of a vast field of inquiry in astronomy, physics, and geology.

The principal purpose of each of these expeditions was the measurement of an arc of a meridian of the Earth, but, in addition to the geodetic measurement, both expeditions took occasion to gather extensive and valuable data in relation to meteorology, terrestrial magnetism, topography, geology, and natural history.

Four hundred years ago, when the memorable discoveries of Columbus, Gama, and Magellan doubled in a single generation all that had been previously known of the surface of the Earth, the spherical form of the globe ceased to be a scientific theory and became a demonstrated fact; and a new era of geography was opened in which men, believing the globe to be a sphere, began to make rude measurements upon its surface to ascertain its size. These measurements, as we know, at length, after nearly two centuries, reached an extent and precision sufficient to prove that its surface was not

spherical. Then the Earth came to be looked upon as a spheroid of revolution, and, with the lapse of time and the accumulation of measurements, the dimensions of the spheroid that represents the actual globe more closely than any other spheroid have been determined. But, as further and more accurate data are measured, alterations in these elements are sure to follow, and to show more and more precisely wherein the actual geoidal form differs from a spheroid of revolution and whether a better approach to its mathematical form woud be arrived at by viewing it as an ellipsoid with three unequal axes, or else as an ovaloid.

Eratosthenes, who lived in the third century before the Christian era, seems to have been the first to conceive the principles and make the observations necessary for a logical deduction of the size of the Earth. He noticed that at Syene, in Southern Egypt, the sun at the summer solstice being directly in the zenith cast no shadow of a vertical object, while at Alexandria, in Northern Egypt, the rays of the sun at the same time of the year made an angle with the vertical of one-fiftieth part of four right-angles. From this he concluded that the circumference of the Earth was fifty times the distance between these two places, and this being, according to the statements of travellers, 5,000 stadia, he announced that the whole circumference was 250,000 stadia. The exact length of the stadium is now unknown, so that the precise evaluation of the result of this calculation by Eratosthenes cannot be stated, but it is not thought to differ greatly from the real length of the circumference of the globe.

Such, in its simplest form, is the conception of the geodetic operation usually called the measurement of the arc of a meridian, which, for its successful execution, demands the most accurate instruments, the best observers, and long-continued labour. It is simply to measure the distance between two points on the same meridian, and find their difference in latitude. The determination of the difference of latitude is now usually made by zenith telescope observations at each station, and is perhaps the easiest part of the work. The length of the observed line of the meridian is more difficult to obtain, since it is usually impracticable to find a line of sufficient length running due north and south, and level enough to be directly measured with the implements for linear measurement. Ordinarily, the terminal points are situated on different meridians, and the length of the meridian intercepted between their parallels of latitude has been customarily found, ever since the days of the Hollander, Snellius, by calculation from a triangulation carried on between them. By this method, a

long chain of triangles is formed and all the angles of them are carefully observed. One, at least, of the sides is located on a level plain, where it may be precisely measured by special implements; and, by finding the elevation above the ocean of the ends of this base, its length, and hence the whole triangulation, may be reduced to that surface. For it has been decided that the form of the mean level of the surface of the ocean is the form which a spheroidal surface deduced from geodetic measurements should be designed to represent. Astronomical observations are made at the triangulation stations to determine the latitudes and the azimuths of the sides of the triangles with reference to the meridian; and then, from the known length of the measured base and the known angles, the lengths of all the sides of the triangles and the geodetic positions of the stations are computed. A meridian of longitude is then conceived to be drawn north and south through the triangulation, and also parallels of latitude through each of the stations, and the lengths of the intercepted portions of the meridian between these parallels are computed and added together to give the length of the meridian between the southernmost and northernmost stations.

Between 1690 and 1718, Cassini carried on surveys in France which were probably more accurate than any preceding geodetic operations; and in 1720 he published results from which it appeared that the length of a degree of latitude on the Earth's surface increased toward the equator and decreased toward the poles, or, in other words, that the Earth was a spheroid that is prolate or extended at the poles, and not flattened, as had been determined from the discussion of Richer's observations by Newton in Book III of the first edition of his Principia, published in 1687. Richer, having been sent to Cayenne, in equatorial South America, on an astronomical expedition, noted that his clock, which kept accurate time in Paris, there continually lost two seconds daily, and could only be corrected by shortening the pendulum. Men were then aware that the time of oscillation of a pendulum depends upon the intensity of the force of gravity, and Newton showed, after making due allowance for the centrifugal force, that the force of gravity at Cayenne as compared with that at Paris was such that Cayenne was further from the centre of the globe than Paris, and that, therefore, the Earth was an oblate spheroid, flattened at the poles. As a result of the dispute that arose among philosophers of those days as to whether the shape of the globe was a spheroid flattened at the poles, as indicated by the investigations of Newton, or a spheroid extended at the poles and flattened around the equator, as appeared from the work of Cassini,

the French Academy resolved to reach a definite settlement of the question by sending out two expeditions with the object of measuring two meridian arcs, one in the equatorial and the other in the polar regions. Accordingly, two parties sailed in 1735—Clairaut and Maupertuis to Lapland, and Bouguer, La Condamine, and Godin to Peru. The Lapland party measured its base on the frozen surface of the River Tornea, executed its triangulation and latitude observations, and returned to France in less than two years with data which gave for an arc of the meridian of 1°-37′-19.57″ a length 180,287.7 meters, and for a length of 1° of latitude 111,949 meters. The Peruvian expedition was absent about seven years, and set out stations forming forty-three triangles between Cotchesqui and Tarqui, which are about 220 miles apart. Two sides of these triangles were carefully measured several times with wooden rods. From these bases and the measured angles the length of the meridian intercepted between the parallels of latitude of the two extreme stations was found to be 344,736.8 meters, while from the astronomical observations the difference of latitude of these stations was 3°-07′03.46″, and the length of 1° of latitude 110,565 meters. Since the surveyors neglected to determine the elevation of their base lines, exact means for reducing the triangulation of this elevated Peruvian arc to the mean level of the surface of the ocean, to which all other geodetic measurements entering into the modern discussions of the size and shape of the Earth have been referred, have never been supplied. At the same time, the Cassini surveys of France gave a value intermediate between the other two for the length of 1° of latitude in that part of the world.

If the Earth were a perfect sphere, one arc of a meridian measured with precision would be enough to determine the value of its radius; but as it is plainly a spheroid, and as a spheroid requires that two dimensions be known in order that its size be determined, it is evident that at least two measured arcs of meridians are required. And when the three measures that were derived from the surveys in Lapland, France, and Peru were taken, two and two, for the purpose of deducing the size and shape of the Earth, each of the three combinations of data gave a different value for the ellipticity of the meridian, whereas, if the Earth were really a spheroid of revolution and if the measurements were truly made, these values of the ellipticity should be the same. To settle the question as to whether the assumption of a spheroidal surface is incorrect or the surveys were inaccurate, a number of meridian arcs were measured in different parts of the world during the course of the follow-

ing generation or two, and a culmination of the eighteenth-century undertakings of this nature was reached in the investigation by the French for the derivation of the length of the meter. This work was under the charge of the celebrated astronomers Delambre and Méchain, and the meridian arc extended from the latitude of Dunkirk on the north to that of Barcelona on the south, embracing an amplitude of nearly ten degrees. In this survey the methods of the measurement of bases and angles were greatly improved, and were brought within the range of comparison with similar works of modern precision, as has been proved by the measurement of this meridian arc, executed, during the years between 1870 and 1892, by Perrier and Bassot. This latter survey was joined on the north with the chain of triangles extending northward over Great Britain to the Shetland Islands and on the south to the triangulation which spreads southward not only over the Spanish peninsula but beyond into Algeria, so as to embrace within its present extremities an amplitude of about 29 degrees. Indeed, during the nineteenth century, the vast extension of trigonometrical surveying in the principal seats of enlightenment and wealth in the northern hemisphere resulted in a great increase in the store of observations, relating to the middle latitudes, for conducting mathematical investigations with a view of determining the size and shape of the Earth; and there have been published many investigations and combinations, made according to the method of least squares or the principles for the adjustment of observations that were announced by Legendre and elaborated by Gauss in the early part of the last century. The most important of these are the ones published by Bessel in 1841 and by Clarke in 1866 and in 1880. The material employed by Bessel consisted of the Peruvian and Lapland arcs and eight others situated in Russia, Prussia, Denmark, Hanover, England, France, and India. The sum of the amplitudes of these arcs is about 50.5°, and they include 38 latitude stations. In the discussion of 1866 by Clarke, the data were derived from the Peruvian arc and five others situated in Russia, Great Britain, France, India, and South Africa, including 40 latitude stations and embracing a total amplitude of over 76°. The rediscussion by Clarke, published in 1880, deduces the elements of an oblate spheroid which will best satisfy the ellipsoidal and geoidal forms which have been the subject of the most important modern contributions to our knowledge of the figure of the Earth. The material employed includes, again, the ancient Peruvian arc, together with the modern triangulation extending over Great Britain and France, the Russian arc of 25°, the Indian arc of 24°, and one

at the Cape of Good Hope of 4½°, making a total of nearly 80° in amplitude, with 56 latitude stations.

In the modern discussions, the older measurements have been superseded by the results of more recent and precise operations, excepting in the instances of the measurements made under the auspices of the French Academy in the first half of the eighteenth century in the very high latitudes and the very low latitudes. The Lapland arc was short and the Peruvian arc was not reduced to the sea-level, and in relation to both of them the instrumental means were lacking for arriving at the degree of precision which is now attained in such measurements. Indeed, marvellous advances have been made in geodetic science during the last one hundred and fifty years, not only in instrumental precision but in the theoretical methods of computation. At the beginning of the nineteenth century, for instance, the measurement of the angles of the geodetic triangle was so crude that the spherical excess remained undetected, and the process of adjustment by the method of least squares was entirely unknown. The zenith telescope for latitude observations, the electric telegraph for longitude determinations, the self-compensating base apparatus, the method of repetitions in angle measurements, the comparison of the precision of observations by their probable errors, and their adjustment by minimum squares—all these and many other improvements were introduced and perfected during the nineteenth century; and during the same time the theory of geodesy has demonstrated that the mathematical figure of the Earth may be determined independently of any hypothesis concerning the law of its formation, provided that there have been observed at and between numerous stations five classes of data—namely, astronomical determinations of latitude, longitude, and azimuth, base-line and triangulation measurements, vertical angles between stations, spirit-levelling between stations, and determinations of the intensity of the force of gravity. And although many generations must pass away before sufficient data have been accumulated to provide for a thorough discussion answering all the demands of geodesy, yet every important contribution may be influentially applied in the evaluation of those more prominent deviations of the Earth from a spherical form which account for certain irregularities in the motion of the moon and for the precession of the equinoxes, which must enfold within its age-long progress much that will influence the destiny of the Earth.

And so we come to the point of view from which the purpose of the recent measurements of arcs of the meridian in Spitzbergen and in the Equatorial Andes may be plainly seen.

The Quito Meridian Arc.

(*See map.*)

The French undertook their mission in Ecuador as a result of proceedings that were initiated at the meeting of the International Geodetic Association in 1889. The Minister of Public Instruction in France, after consultation with the Minister of War, decided to confide the mission to the geodetic section of the Service Géographique de l'Armée. On account of political disturbances in Ecuador, the year 1899 arrived before the important preliminary reconnoissances, which were recognized as indispensable to the full success of the geodetic operations, were carried out.

In 1900 an appropriation of 500,000 francs was made by the French Government for the purpose of executing the objects of the mission, and in April, 1901, an expedition composed of five officers, a military surgeon, and seventeen non-commissioned officers and enlisted men embarked for Colon and Panama. They commenced the operations in Ecuador in July, 1901.

If it be asked why the French chose to carry forward these important observations here, in a region that formerly belonged to Spain and now belongs to Colombia, Ecuador, and Peru, the answer is that, on examining the continental masses traversed by the equator of the Earth and finding them to be Ecuador, Brazil, French Congo, Central Africa, and the region of the Great Lakes of Africa, we conclude that Ecuador is the best place, because the plain of the Amazon is too unhealthy, the Congo region too lacking in resources, and Central Africa too little known.

The Pacific side of the American continent is bounded by a chain of mountains of varying elevation whose summits in South America, where the chain is known by the name of the Cordillera of the Andes, reach and surpass an altitude of 6,000 meters. In Ecuador a striking feature of these mountains is that they are double, forming two elevated, parallel chains called the Cordillera of the East and Cordillera of the West. And between these two chains there is a fertile, populous, and cultivated valley, consisting of a succession of basins separated from one another by spurs joining together the two Cordilleras. The network of triangulation established by the geodesists extended from north to south throughout this inter-Andean region, utilizing the summits of both of the bounding chains of mountains for placing the triangulation, astronomical, gravity, and magnetic observation stations.

Upon landing in Ecuador the expedition proceeded inland from

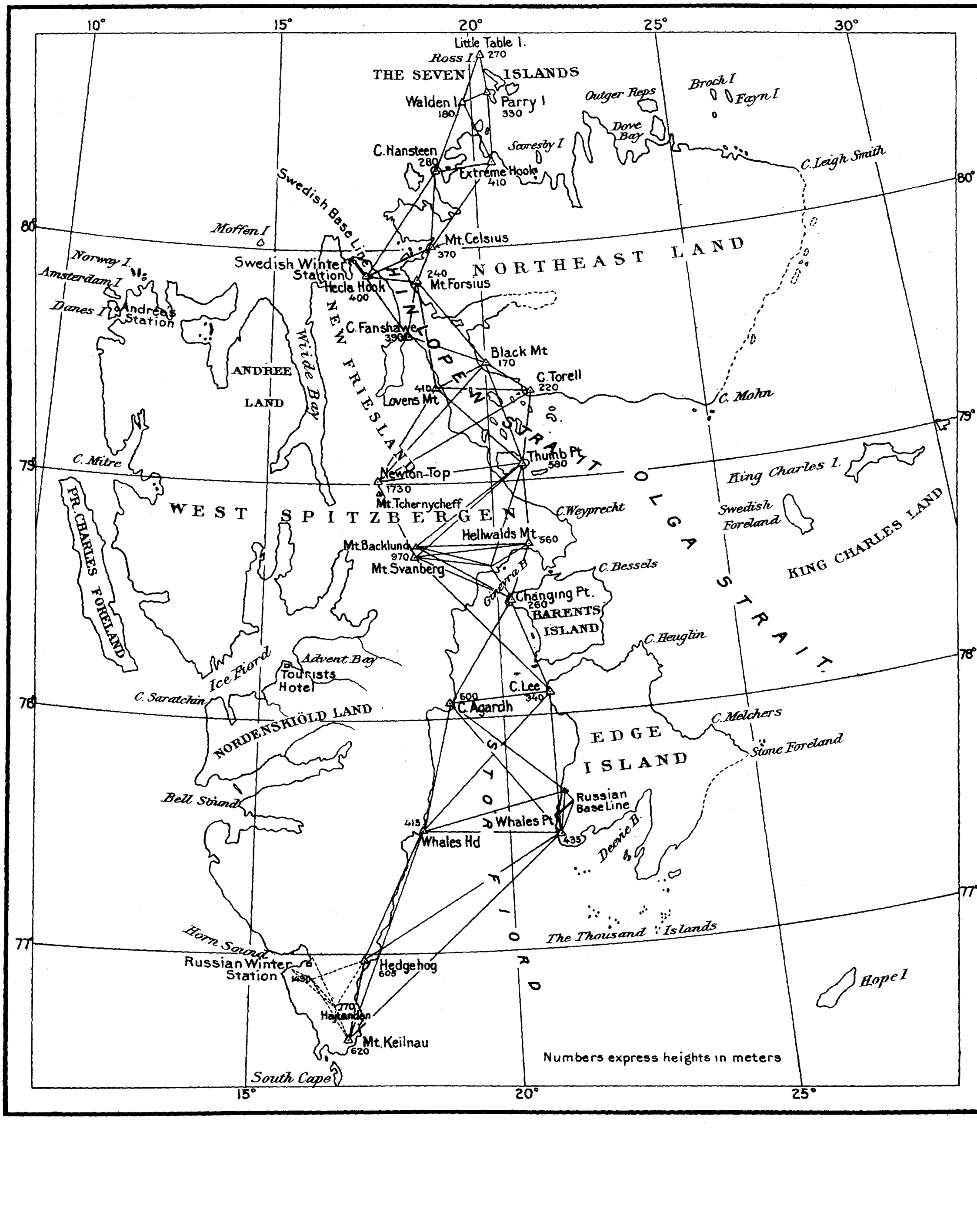
Guayaquil to Riobamba, which is in the centre of the valley between the Cordilleras, and, during a sojourn of three months in this region, measured the principal base-line of the triangulation and determined the fundamental astronomical elements of latitude, longitude, and azimuth. The delicate operation of measuring the Riobamba base-line was carried out by clearing and grading a lane from 5 to 6 meters wide for a distance of about 10 kilometers in a nearly level region, and marking its extremities by two masonry pillars in which were embedded blocks of bronze, which bore the limiting marks whose distance apart was to be found. Two measurements were made—the first with the bimetallic base-bar of the Service Géographique, constructed by Brünner; and the second with Järderin's base-measuring apparatus. The base-line at Tulcan, at the northern end of the arc, was measured with Järderin's apparatus alone, while the base-line at Payta, in Peru, at the southern end of the arc, was measured with the new Invar base-bar of the Service Géographique and also by the Järderin system, using three Invar tapes. The two measurements of the Riobamba base-line differed by only 1/500,000 of the total length.

The base-lines having been measured, it was necessary to reduce their lengths to what they would be on the geoid, which is the theoretical surface upon which the triangles are calculated, and corresponds to the surface of equilibrium of the waters of the ocean supposed to be extended under the land and over all the Earth. To ascertain exactly the altitude above the mean level of the sea of the ground upon which the base was situated, it was necessary to run a line of precise spirit-levelling from one of the terminals of the base-line to a position on the sea coast, where a tide-gauge had been installed for the purpose of determining the position of mean sea-level.

Each triangulation station throughout the entire chain of triangles was marked by a cross traced on a block of bronze sealed in the masonry pillar which was built to support the instrument of observation. For the measurement of horizontal angles, an azimuth circle, read by four microscopes, was used; and for the determination of zenith-distances and cutting in points of the third order, the theodolite of the Service Géographique, read by two microscopes. The same theodolite or an astrolabe served for the observations that were made to determine the astronomical latitudes.

When the work of measuring the Riobamba base-line was finished, the expedition was divided into two parties, one of which carried on the work of triangulation while the other measured the

THE TRIANGULATION OF THE SPITZBERGEN MERIDIAN ARC



verification bases at Tulcan and Payta, and determined the latitudes of the extremities of the arc in order to provide data for the evaluation of its total amplitude.

The operations at each triangulation station consisted of the installation of a camp for the observers, the establishment of a block of masonry containing the bronze datum representing the precise position of the station, the construction of a pier about a meter high covering the mark and intended to support in turn the instrument and the wooden signal which was designed to be seen from other triangulation stations. Since in the morning and the evening the vibrations of the air produced by the heating of the atmosphere by the sun's rays are least felt, these periods of the day were employed in measuring the horizontal angles, and the middle part of the day was set aside for the measurements of zenith-distance to serve in determining the relative altitudes of all the triangulation stations. Favourable times were also seized upon for the execution of the topography, the measurement of the magnetic elements, the preparation of star-catalogues, and the computation of field reductions.

Distributed throughout the arc, which has an amplitude of 5° 53′ 34.2″, there were eight fundamental astronomical stations at which the latitude, longitude, and azimuth were determined.

Pendulum observations for measuring the intensity of the force of gravity were made at six stations distributed along a line which traversed the two Cordilleras in order to afford an account of the effect of the considerable relief of the Andes. These observations were made generally in caves or such other surroundings as would insure a minimum variation of temperature during the course of the experiments.

Studies in natural history, ethnography, anthropology, and linguistics were pursued by the surgeon of the expedition, and the magnificent collections resulting from his work have been deposited in the Muséum d'Histoire Naturelle de Paris.

The computations and reductions are not yet completed, but there is reason to believe that the degree of precision necessary to the success of the enterprise has been reached.

The Spitzbergen Meridian Arc.

(*See map.*)

The idea of measuring an arc of the meridian in Spitzbergen was first proposed by Sabine, who had determined the intensity of the force of gravity here in 1823, and thirty years afterwards Torell

induced the Academy of Sciences at Stockholm to attempt a detailed reconnoissance of this archipelago, with a view of determining whether the proper conditions for the execution of such work could be found in this part of the world. They sent Chydenius and Dunér to make an examination, but, on account of the influences of bad weather, a second expedition had to be sent out for this purpose. This second expedition, which was under the direction of Nordenskiöld and Dunér, solved the problem with full success and showed the existence of easily accessible and intervisible elevated points near the coasts which might serve for the location of the stations for extending a chain of triangulation from South Cape in latitude 76° 30′, to Ross Island, at the northern extremity of the archipelago, in latitude 80° 50′, and thus providing for the measurement of an arc of the meridian of about 4° in extent, lying within about 1,000 kilometers of the North Pole. Forty years elapsed, during which the demands of science grew stronger and stronger for the precise measurement of a polar arc of the meridian, before the Academy of Stockholm again took up the question and appointed Professor Rosen to prepare a detailed plan for an astronomical and geodetic expedition to Spitzbergen, to be presented in 1896. This proposition was accepted by the Swedish Academy, which the next year laid before the Imperial Academy of Sciences of St. Petersburg an invitation to join in the execution of this great scientific project. The King of Sweden and the Emperor of Russia both appointed commissions to mature the plans, and in 1898 the work commenced by the sending forth of a preliminary expedition composed of members from both countries to make a final reconnoissance of the territory to be traversed and to erect some of the geodetic signals.

The next year the fully-organized Russo-Swedish expedition started out, equipped not only to carry on the astronomical and geodetic observations incident to the measurement of the arc of the meridian, but also to make observations in relation to geology, botany, zoology, meteorology, and terrestrial magnetism; and, for the more effectual accomplishment of these latter researches, it was decided that a part of the expedition should winter in Spitzbergen.

The Russian party was embarked in three steamships—the Army transport *Bakane,* the ice-breaker *Ledokol 2,* and the merchant steamer *Betty;* and the Swedish party in two—the ice-breaker *Svensksund* and the steamer *Rurik.* Toward the latter part of June, 1899, all the members of the joint expedition assembled at Tromsö, and on the 25th of June the five vessels set out for Spitzbergen.

Upon arrival there it was decided to divide the geodetic work

into two portions, the Swedish party undertaking the northern part of the triangulation which extends from the northern extremity of the arc down to Thumb Point and embraces 13 stations, and the Russian party occupying themselves with the larger triangles which are formed by the remaining 10 stations to the southward.

The western escarpment of the submarine elevation which culminates in the archipelago of Spitzbergen is due to the folding of ancient geological formations throughout a zone which passes from the Hebrides and Shetland Islands across the western edge of Norway and, going past Bear Island, continues to the westward of Spitzbergen. It is for this reason that the western part of the archipelago is characterized by mountainous ridges running parallel to each other and having serrated crests and isolated peaks reaching altitudes of 1,200 meters in one ridge and more than 1,700 meters in another. In the interior of the archipelago the conditions are quite different from those prevailing in the western part. All that part of the country which bounds the two sides of Stor Fiord and Hinlopen Strait is made up of horizontal strata. Indeed, the greater part of Spitzbergen is occupied by plateaux, and, if its discoverers had found its eastern instead of its western part, it is not probable that they would have bestowed its present name. From the interior plateau, which is almost entirely covered with ice and from which several isolated mountains rise up, enormous glaciers descend seaward both toward the east and the west.

The difficulties of making precise instrumental observations in the field were vastly increased by the extreme features of the climate, the dangers of travel, and great labour of transporting the heavy instruments, the tents, and the supplies of food, upon sledges or upon the backs of men, up the steep slopes to the stations, where, enshrouded in ice and storm, the observers would wait for weeks and weeks for the period of clear, transparent atmosphere that was sure to follow, sooner or later, to enable them to secure their observations.

The Swedish winter quarters were established at Treurenburg Bay, near Mt. Hecla, and the Russian winter quarters on the eastern shore of Horn Sound. At these places were installed the instruments that were needed for the observation of the magnetic, meteorological, and other phenomena that require continuous registration.

The base-line measured by the Swedish party was near the Swedish winter quarters, on the flat lying between Treurenburg Bay and Hinlopen Strait, and extended for a distance of about 10,000

meters in a direction nearly parallel to the general trend of the network of Swedish triangulation. The Russian base-line was measured on the eastern shore of Stor Fiord in the southwestern part of Edge Island and extended for a distance of about 6,200 meters through a marshy valley nearly at sea-level. Both bases were measured with a high decree of precision by Järderin's method with Invar tapes, in which the coefficient of expansion is very small.

Latitudes were determined at all the triangulation points and at six other stations, making twenty-nine determinations in all. This will provide one astronomical latitude for each nine minutes of the measured arc, so that an unusually exact study of the surface form will be practicable. Twenty-three azimuths were determined, and the influence on astronomical observations of the attraction of adjacent land-masses was ascertained. Pendulum experiments for the measurement of the intensity of the force of gravity were also made at selected stations. A map of the region traversed is forthcoming on a scale of 1/200,000, and special maps of the surroundings of the triangulation stations on larger scales. The general map will consist of five sheets, and three of these will be prepared by the Russians.

The scientific results of the expedition are being published in the French language in a series of mémoires. They are separated into two principal divisions, one for each nation; and comprise the following subjects:

TOME I: ASTRONOMY AND GEODESY.

Section I. History of the Expedition.

II. Geodetic Operations.
 A. Base-line measurements.
 *B. Measurement of horizontal and vertical angles.
 C. Adjustment of triangulation.

III. Astronomical Operations.
 A. Determination of time.
 B. Determination of azimuths.
 C. Latitudes.
 D. Longitudes.

IV. Intensity of the force of gravity.

*V. Tidal observations and precise levelling.

VI. Results of the combination of the geodetic and astronomical observations.

TOME II: TERRESTRIAL PHYSICS, METEOROLOGY, NATURAL HISTORY.

Section VII. Terrestrial Magnetism.
- *A. Magnetic Survey of Spitzbergen.
- B. Observations of variations of the magnetic elements.

VIII. Meteorology.
- *A. Regular observations at the winter quarters.
- *B. Solar radiation.
- *B^i. The state of the ice and snow.
- *B^{ii}. Forms of the ice-crystals.
- *B^{iii}. Meteorological observations made at the mountain stations.
- *B^{iv}. and B^v. Meteorological and hydrographic observations made at sea.
- *C. The aurora borealis.

IX. Topography and Geology.
- A. Topographical description of the region explored.
- B. Geology.

X. Botany.

A number of the Swedish mémoires have already been received in this country, and are marked by asterisks in the foregoing list. While working separately for publication in all else, it has been concluded that the commissions shall work together in the reduction of the final results of the four years' work, involving a comparison of the astronomical and geodetic results.

THE ANGLO-RUSSIAN AGREEMENT AS TO TIBET, AFGHANISTAN, AND PERSIA.

BY

ELLSWORTH HUNTINGTON.

On September 25th, the British and Russian Governments published the text of a convention as to the sphere of action of each of the two countries in Persia, and as to their relation to Afghanistan and Tibet. The convention does not attempt to interfere with the